SCHOOL OF

CIVIL ENGINEERING

INDIANA

DEPARTMENT OF TRANSPORTATION

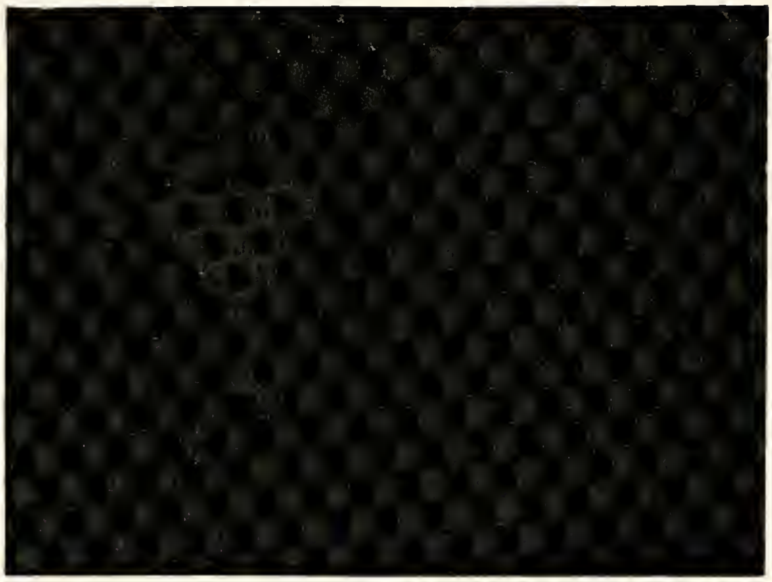
JOINT HIGHWAY RESEARCH PROJECT

FHWA/IN/JHRP-92/4
Final Report

GUIDELINES FOR TRAFFIC IMPACT ANALYSIS OF DEVELOPMENTS ALONG STATE HIGHWAYS

Soumya Dey
Jon Fricker

PURDUE UNIVERSITY



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by

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16. Abstract

With intensification urban development and dwindling public resources, assessing the impacts of a new development (traffic impact analysis) is becoming an important planning tool for transportation engineers, so that the traffic impacts of new developments can be foreseen and effective mitigating measures can be planned using optimal allocation of the available funds. The study establishes a detailed and standardized methodology for traffic impact analysis. Although the procedure was developed for the Indiana Department of Transportation, it can be used by other transportation agencies as well with little or no modification.

A new methodology for estimating the percentage of pass-by trips using a license plate survey (instead of the traditional interview survey) is presented. The report also demonstrates how Bayesian statistics can be used to update the national ITE Trip Generation data base with limited local data to derive more reliable local trip generation rates. A status report of traffic impact analysis and impact fees in various state transportation agencies has also been included. A brief discussion on impact fee structure has been incorporated.

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IMPLEMENTATION REPORT

The implementation of the procedures developed in the project "Guidelines for Traffic Impact Analysis of Developments Along State Highways", which are described in the project's Final Report, Applicant's Guide, and Reviewer's Guide, ought to consist of:

1. **Distribution** of the report and guides to appropriate individuals.
2. **Training** of appropriate individuals in the methods and procedures associated with Traffic Impact Analysis.
3. **Coordination** of the activities undertaken by the various individuals involved in the planning of developments, the preservation of traffic operations, the conduct of impact studies, and the review of such studies.

Distribution

Copies of the Applicant's Guide should receive the widest possible dissemination. Engineering consulting firms with a history of having performed Traffic Impact Studies in Indiana should receive the Applicant's Guide, as should developers through their state organization. Metropolitan planning organizations (MPOs) should receive the Reviewer's Guide, which includes the material contained in the Applicant's Guide, plus material on techniques currently considered acceptable for traffic impact analysis.

To increase the degree of coordination between developers and highway agencies at state and local levels, local public agencies should be informed of the existence of the Applicant's Guide. This could be done through the Highway Extension Research Project for Indiana Counties and Cities.

Training

The contents of the Reviewer's Guide should be compared against the experiences of those INDOT personnel who have worked in activities related to traffic impact analysis. At INDOT's central office, this would include personnel in the Permits Section, the Design Division, and Operations Support. Because much of the permit granting authority has been delegated to the districts, each district Traffic Engineer and Regulatory Supervisor should attend the discussion of the Reviewer's Guide. It would seem appropriate to have a special meeting of INDOT personnel for the first such "discussion". Subsequently, an annual review of recent experiences and proposed new methods could take place in conjunction with other events, such as Road School. This will ensure that the decisions being made around the state with respect to access and traffic engineering improvements are reasonably consistent. At these annual updates, new participants can hear what more experienced personnel have learned, and a joint meeting with consultants and local public officials could be scheduled.

Coordination

To improve the timing and quality of traffic impact analyses done throughout Indiana, the standard procedures adopted by INDOT should be widely disseminated to consulting engineers, MPOs, and local public agencies (LPAs). When the procedures evolve, such that the contents of the guides produced by this project no longer reflect INDOT procedures, the guides should be updated. To the extent that INDOT districts, consulting engineers, MPOs, and LPAs all become aware of the INDOT procedures, and these parties become a part of the refinement of those procedures, the coordination necessary for a mutually desirable resolution of the conflict between access rights and traffic efficiency will be accomplished.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

One of the fundamental aspects of transportation planning is the interdependency of land use and transportation. The pattern of land use is affected by the level of accessibility provided by the existing transportation system. Any new development leads to the production and/or attraction of trips and thus creates new travel demands. Hence there is a need for improvement of the existing transportation facilities -- either in the form of new infrastructure or in the form of improved operational conditions. Such improvements, in turn, make the land more accessible to the existing activity centers and the attractiveness of the land increases. This spurs new development, and the cycle starts again. This process continues until some kind of equilibrium is attained. The land use transportation cycle is shown in Figure 1.1.

In the short-run, however, the predominant influence is that of land use on transportation [20]. Consequently, there is a need for a standardized methodology to assess the infrastructure or operational improvements needed for the transportation system.

Traffic Impact Analysis (TIA) is a specialized study of the impact that a given type and size of new land use has on the nearby transportation system [2].

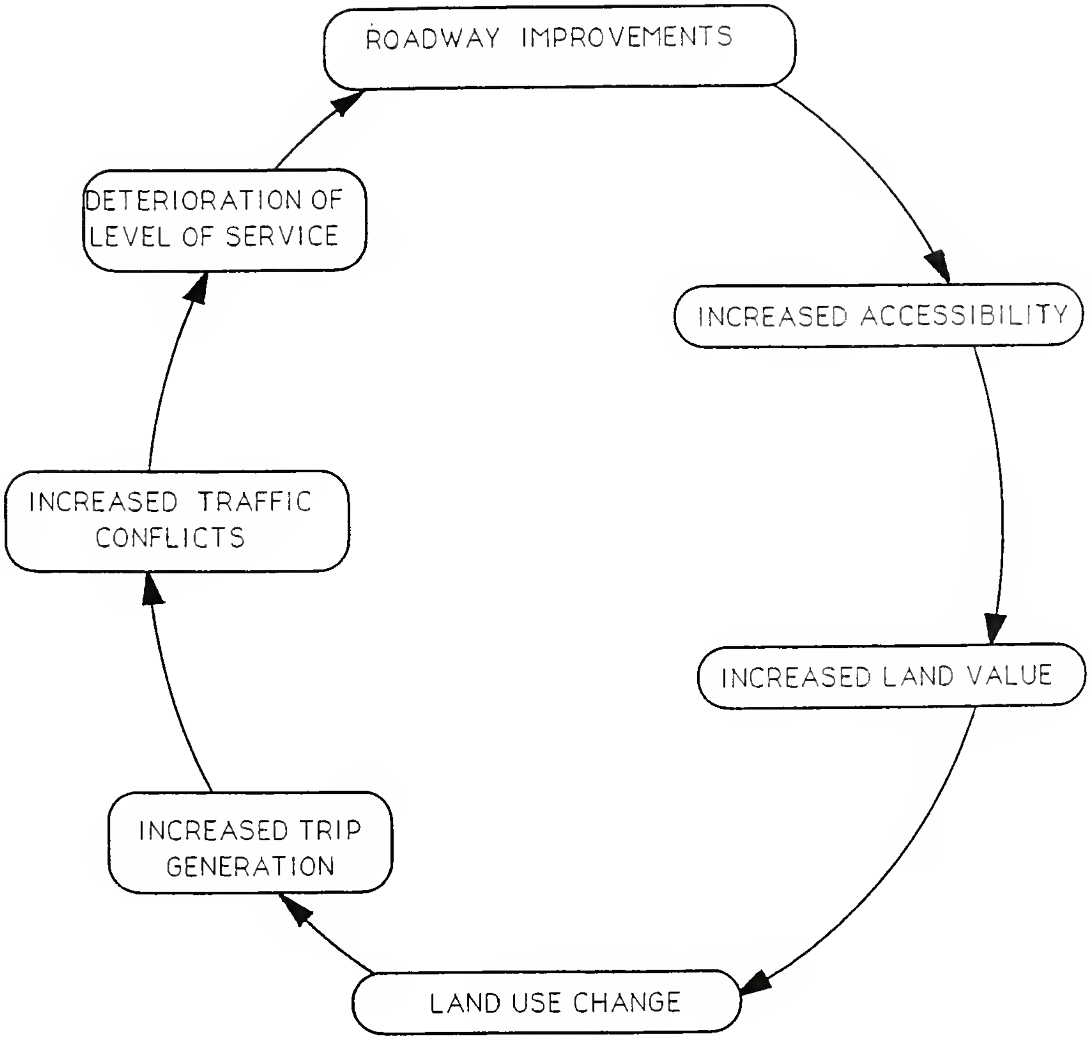


Figure 1.1 Land Use Transportation Cycle

One of the major transportation issues addressed in the 1980's has been the growing concern about the transportation infrastructure not being able to keep pace with development. This imbalance between transportation supply and demand has resulted in congestion, delay and safety hazards at many locations throughout the country. As a result, traffic impact analysis is becoming popular as a planning tool, so that effective mitigating measures can be taken in advance. In fact, in some regions, a traffic impact study is mandatory for any developments larger than a few single family dwelling units.

1.2 Purpose of Traffic Impact Analysis

The main purposes of traffic impact analysis are [22]:

1) To ascertain the operational conditions on the adjacent roadway network when a proposed development is accommodated within the existing transportation infrastructure along with other proposed developments (as reflected in the Comprehensive Development Plan).

2) To identify transportation improvements required to maintain the existing operational conditions.

3) To determine whether access to the proposed development will hamper traffic operations and safety near the site.

4) To identify present or future transportation system deficiencies without the new development.

5) To provide decision makers with a basis for assessing the transportation implications of approving proposed zoning changes and development applications.

6) To provide a basis for estimating the cost of proposed mitigating measures. Consequently, a traffic impact study can be used to determine the "fair share" of the improvement cost to be paid by the developer.

1.3 Research Background

This research effort is based on an HPR study entitled, "Guidelines for Traffic Impact Analysis of Developments Along State Highways". It was conducted by the Joint Highway Research Project in the School of Civil Engineering at Purdue University in conjunction with the Indiana Department of Transportation (INDOT) and the Federal Highway Administration (FHWA). At the time the study was undertaken, there was no established procedure or guidelines for requesting, preparing and/or reviewing a traffic impact study (TIS) for a proposed development that would affect state highways. Cases of rezoning and building permits were handled at the local level (City, County, etc.), each of which had its own guidelines, if any. Often, INDOT is not involved in the transportation aspects of a site's development until access permits are requested for access to state routes. This can occur too late in the development's construction for any traffic-related problems to be remedied as effectively and economically as they could have been in the planning stage. Hence the need for a standardized TIA procedure and greater coordination between INDOT and the local transportation agencies was felt.

1.4 Research Objective

The major objective of the research project was to establish a standard traffic impact analysis methodology for

the Indiana Department of Transportation to ensure consistency in study requests and study procedure. The developed procedure has been described in a separate document entitled "Manual of Traffic Impact Studies". At a later stage, requests were made to include a discussion on impact fee structure in different parts of the country. The study also addresses some other issues related with traffic impact analysis. Two major problems that transportation engineers face while conducting a traffic impact study are: (a) determination of reliable local trip generation rates for a proposed development, and (b) estimation of the percentage of pass-by trips for a proposed development. The possibility of using license plate survey (instead of the traditional interview survey) to estimate the percentage of pass-by trips has been investigated. A procedure for using Bayesian statistics to obtain more reliable local trip generation rates has also been included.

CHAPTER 2

STATUS OF TRAFFIC IMPACT ANALYSIS AND IMPACT FEES IN STATE TRANSPORTATION AGENCIES

2.1 Introduction

Before developing a methodology of traffic impact analysis specifically tailored to fit the needs of the Indiana Department of Transportation, it was felt that a survey of the existing policies and standards in other state departments of transportation (DOTs) would prove useful. Therefore, as a part of this study, a survey questionnaire (shown in Appendix A) was developed to find out the status of traffic impact analysis and impact fees in various states. The questionnaire was mailed to all the state DOTs for completion. Forty-two states and the District of Columbia responded. This corresponded to a response rate of about 84 percent. Since the work was being done for INDOT, the status of Indiana in the areas of traffic impact analyses and impact fees was already known.

2.2 Study Findings

The findings of the survey have been categorized into different sub-headings and discussed below. A summary of the survey results is shown in Figure 2.1 near the end of this chapter.

2.2.1 Traffic Impact Study Methodology

Twenty-three states already have a standard methodology for traffic impact analysis. Seven are trying to establish a standard methodology, while 9 states do not require any traffic impact analysis to be conducted for proposed developments. Five states conduct traffic impact analysis under special circumstances only, such as for very large developments.

2.2.2 Research

Overall, 10 states are conducting some form of research on traffic impact analysis and related areas. Thirty-four states do not have any ongoing research on traffic impact analysis. Of the 10 states that are conducting research, 6 are doing advanced research (beyond trying to establish a standard methodology for requests, preparation and review of traffic impact studies). Colorado, for example, is trying to develop access management regulations. Maryland seeks to establish uniform guidelines for statewide review of traffic impact studies. New Jersey is trying to determine a methodology for assessing a "fair share" financial contribution by the developer.

2.2.3 Study Request

Of the 30 states that already have a standard procedure or are trying to establish one, 8 request a traffic impact study during the access permit stage, 4 during rezoning/land use change applications, 3 during the building permit stage, and 12 as early in the development process as possible. The

remaining three states with a procedure did not specify any timing for a study request.

2.2.4 Study Warrants

One of the major purposes of the survey was to determine the "trigger mechanism" or "threshold value" that different states use to determine whether or not a detailed traffic impact study is required for a proposed development. However, most of the states did not specify a quantitative threshold. Some of the thresholds used by different states are shown in Table 2.1.

2.2.5 Trip Generation Data Source

Of the 30 states that require a traffic impact analysis, 18 depend entirely on the trip rates given in the latest edition of the ITE <u>Trip Generation</u> report. Eleven states try to use local data. In the absence of local data they use trip rates from <u>Trip Generation</u>. Three of these eleven states, i.e., Nevada, New Jersey and New York use local trip generation rates for casinos, fast food restaurants and shopping centers, respectively. District of Columbia always requires the use of local data.

2.2.6 Pass-by Trips

For estimating the percentage of pass-by trips, 17 states depend entirely on ITE data, while 7 try to use local data from any previous data collection effort or from previously conducted studies. In the absence of such data, they use the ITE rates with adjustments to reflect the local character-

Table 2.1. Threshold Values for Traffic Impact Analysis

THRESHOLD VALUE	STATE
1. <u>Based on Size of Development</u>	
60,000 square foot or 20 acres	Maine
2. <u>Based on Vehicles per Day</u>	
100 trips per day (for residential developments)	New Mexico
500 vehicles per day	Oregon
1000 vehicles per day on driveway	Florida
5000 vehicles per day	Michigan
3. <u>Based on Peak Hour Trip Generation</u>	
200 peak hour trips	New Jersey
100 peak hour trips	New York, Nevada
75 peak hour trips	Vermont
50 peak hour peak directional trips	Maryland
4. <u>Based on Type of Land Use</u>	
All new industrial/commercial developments	New Mexico

Table 2.1, continued

THRESHOLD VALUE	STATE
5. Based on Level-of-Service	
When level-of-service of adjacent streets deteriorate due to site generated traffic	Colorado
When level-of-service deteriorates to LOS D	Delaware
6. Miscellaneous	
At the discretion of the reviewer	Virginia, Wyoming, New Hampshire, Montana, Minnesota, North Carolina
When a traffic signal is warranted	Mississippi
When trip generation rate of the zone increases by more than 20% because of a proposed development	Michigan

istics. Some of these 7 states collect data if necessary. Three states do not incorporate pass-by trips in their analyses and 3 other states did not respond to this question.

2.2.7 Mixed-Use Developments

When dealing with mixed-use developments, 6 states use the method described in the ITE Trip Generation report. This basically involves a reduction in the trip generation rates of the individual land uses by 25 percent to account for the internal trips made within such developments. Six other states try to ascertain the percentage of internal trips from local data and prior studies, then subtract the internal trips from the trip generation rate that is obtained by adding the trip rates of the individual land uses ($\Sigma(T/G)_i$ - internal trips). Nine states simply add up the trip generation rates of the individual land uses ($\Sigma\ (T/G)_i$), without adjusting for the internal trips. Six states use miscellaneous methods for estimating trip generation rates of mixed-use developments. These methods include using surrogate data or reducing by 33 percent the trip generation rate obtained by adding the rates of the individual land uses (Michigan), using a different predictor variable (e.g., employment instead of floor area - Texas), using results of previous studies (North Carolina, Florida), etc. Three states did not respond to this question.

2.2.8 Acceptable Level-of-Service

Question 9 was asked in order to help evaluate how "adequacy" is defined by various state departments of transportation. Table 2.2 shows what the states assume to be an acceptable level-of-service.

Table 2.2 Acceptable Level-of-Service

ACCEPTABLE LEVEL OF SERVICE	# OF STATES
Rural - LOS B, Urban - LOS C	2
Rural - LOS C, Urban - LOS D	5
LOS C	2
LOS C to LOS D	4
LOS D	8
LOS C desirable, LOS D acceptable, LOS E tolerable for small periods of time	1

2.2.9 Impact Fee/Off-Site Improvements

Fourteen states require the developer to pay an impact fee or to provide off-site improvements necessitated by site generated traffic. Twenty-five states do not require any form of impact fee from the developer. In 5 other states, the state department of transportation does not charge any impact fees but the local governments may do so. Some states responded 'no' to the question, although a review of the existing literature on impact fees indicated that some of the local governments in these states have a well-defined policy of assessing impact fees. This was probably due to the fact that those DOTs do not get involved with impact fee assessment.

2.2.10 Developer Commitment

Of the 14 states that require the developer to pay for off-site improvements, 10 states require the developer to make

a commitment or pay during the access driveway permit process, and 2 during the building permit process. Two states did not respond to this question.

2.2.11 Change in Level-of-Service

The findings of question 12 are tabulated below in Table 2.3:

Table 2.3 Responses to Question 12

	CHARGE IMPACT FEE/OFF-SITE IMPROVEMENTS	
	YES	NO
No change in LOS due to site generated traffic	1	7
LOS deteriorates but still operates at acceptable LOS	6	2

2.2.12 Estimating Impact Fees

None of the states that responded and assess impact fees specified any standard method for estimating impact fees. All the states require the developers to either pay for or provide the off-site improvements required to maintain acceptable traffic operational conditions on the adjacent roadway network. Again, the results of the survey contradicted the existing literature, which indicated that many states have formalized a procedure for assessing impact fees. The contradiction may likewise be explained by distinguishing between the state DOTs and local transportation agencies.

2.2.13 Piecemeal Developments

Piecemeal developments refer to a series of developments that have negligible individual impact but substantial collective impact. None of the states have any standard methodology for assessing impact fees for piecemeal developments. Only Oregon tries to make the developer to commit to pay his "fair share" in the future. New Jersey follows a "last developer in" policy. Under this policy, the last developer who causes the system to go from adequacy to inadequacy has to pay for required improvements to bring it back to adequacy, although his individual impact might be relatively small. In New York, Transportation Development Districts (TDD) and Right-of-Way donation are the most common forms of public/private cost sharing for transportation improvements. Cost sharing legislation is pending in New York.

2.2.14 Legal Challenge

None of the states except New York have faced any legal challenge to the concept of impact fees/off-site developments. An October 1989 Appeals Court ruling against the Town of Guilderland's impact fee ordinance has left all New York state localities (and the state department indirectly) without the ability to charge transportation impact fees.

2.2.15 Problems

Some of the problems faced by the state transportation agencies in areas of traffic impact analysis and impact fees are:

i) Applying consistent policy throughout the state

ii) Making developer make off-site developments according to state specification
iii) Questionable analysis by consultant
iv) Application for access not justified by traffic impact study
v) Applicants and consultants feel that study area is unreasonably large
vi) Lack of policy or methodology for determining necessary off-site improvements
vii) Dealing with piecemeal developments
viii) Making developer pay for traffic impacts away from the site
ix) Local politics

2.3 Conclusions

On the basis of the survey responses, the states can be classified into 3 categories. Category 1 is comprised of states that do not require any traffic impact analysis to be conducted. Category 2 consists of states that conduct traffic impact analysis, but do not charge impact fees or do not require the developer to provide off-site improvements necessitated by the site generated traffic. Category 3 includes states that conduct traffic impact analysis and require the developer to pay impact fees or provide off-site developments. Table 2.4 shows the states by categories.

It has to be kept in mind, however, that this classification is based on the survey sent only to state DOTs. For a clearer picture, a more extensive survey has to be conducted, encompassing all the local transportation agencies (city, county etc.) in the different states. Some local agencies have their own guidelines for requesting, preparing and

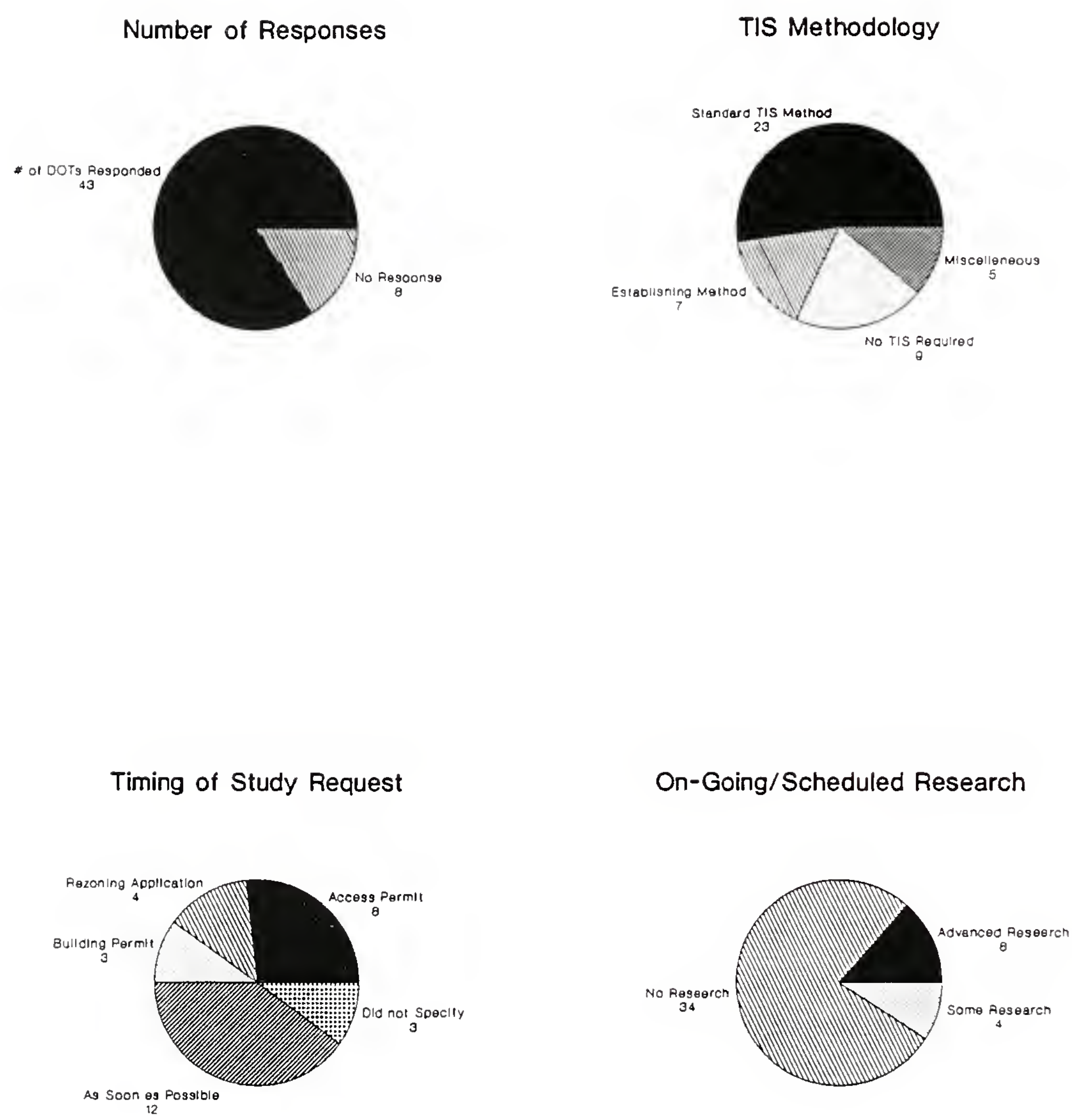


Figure 2.1 Summary of Survey Findings

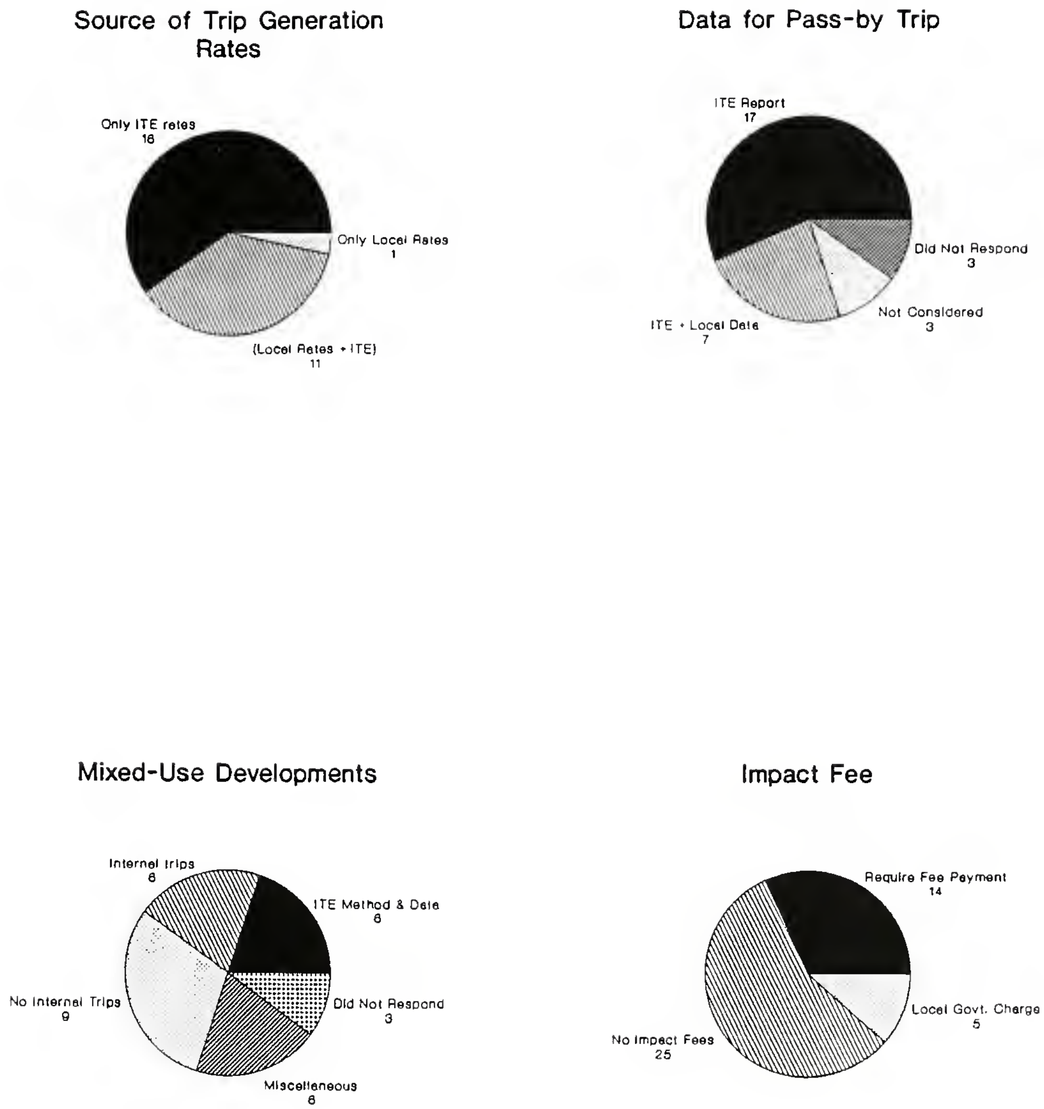


Figure 2.1, continued

Table 2.4 Classification of States Based on Survey Findings

CATEGORY 1	CATEGORY 2	CATEGORY 3
Alaska	Dist. of Columbia	Arizona
Alabama	Florida	Colorado
Arkansas	Georgia	Delaware
Illinois	Hawaii	Maryland
Kansas	Maine	Minnesota
Kentucky	Michigan	Mississippi
Louisiana	Montana	Missouri
North Dakota	Nevada	Nebraska
Oklahoma	New Mexico	New Hampshire
Pennsylvania	Rhode Island	New Jersey
South Carolina	Texas	New York
South Dakota	Utah	North Carolina
West Virginia	Virginia	Oregon
	Wisconsin	Vermont
	Wyoming	

reviewing traffic impact studies for proposed developments. In Indiana and Utah, for example, the state DOT gets involved in traffic impact analysis only when a development requires direct access to the state highway. Similarly, the impact fee is a local issue and the state DOTs usually do not get involved with it. The extensive survey effort needed to get an adequate sample of impact fees among local transportation agencies was beyond the scope of our project. ITE Technical Council Committee 6F-46 is undertaking such a survey. Besides providing good insight into the existing practices in other state DOTs, this study will also enable the state DOTs to compare their approaches to traffic impact analyses with other DOTs.

CHAPTER 3

ESTIMATION OF PASS-BY TRIPS USING A LICENSE PLATE SURVEY

3.1 Introduction

A significant portion of the trips attracted by generators like shopping centers and several other convenience-oriented land uses like banks, gas stations, fast food restaurants, are pass-by trips. Methods for handling pass-by trips in traffic impact analysis exist and have been discussed in Chapter 3 of this thesis. However, there is a dearth of data regarding percentage of pass-by trips for a particular type and intensity of land use.

The traditional way for determining the percentage of pass-by trips is to conduct a face-to-face interview survey. Since this is a time-consuming process and involves lots of personnel, most of the traffic impact studies conducted across the nation either do not consider pass-by trips in their analysis or use the scatter plots and regression equations provided by ITE in the Trip Generation report. In fact, responses to the survey questionnaire (Chapter 2) revealed that 63 percent of the states depend entirely on the ITE data to determine the percentage of pass-by trips. Twenty-six percent of the states try to use local trip generation rates. In the absence of such data, they use the ITE rates. Eleven percent do not incorporate pass-by trips in their analyses. Therefore, 89 percent of the states depend either directly or

indirectly on the ITE database. Unfortunately, however, the size of the database is quite small and the regression equations, when available, have very low R^2 values (on the order of 0.3). Hence, the validity of the curves is not beyond question. Moreover, using these curves blindly would fail to take into account the site-specific characteristics of the development under consideration.

In the 1991 edition of the Trip Generation report, a new methodology for estimating the percentage of pass-by and diverted linked trips has been suggested, based on the volume of the traffic available to produce pass-by and diverted linked trips (shown in Figure 3.1) multiplied by an attraction factor related to the size of the development. The following set of equations are suggested [5]:

$$N_{pb} = p \times VOL_{pb}$$
$$N_d = p \times VOL_d$$
$$p = a_0 + a_1 G$$

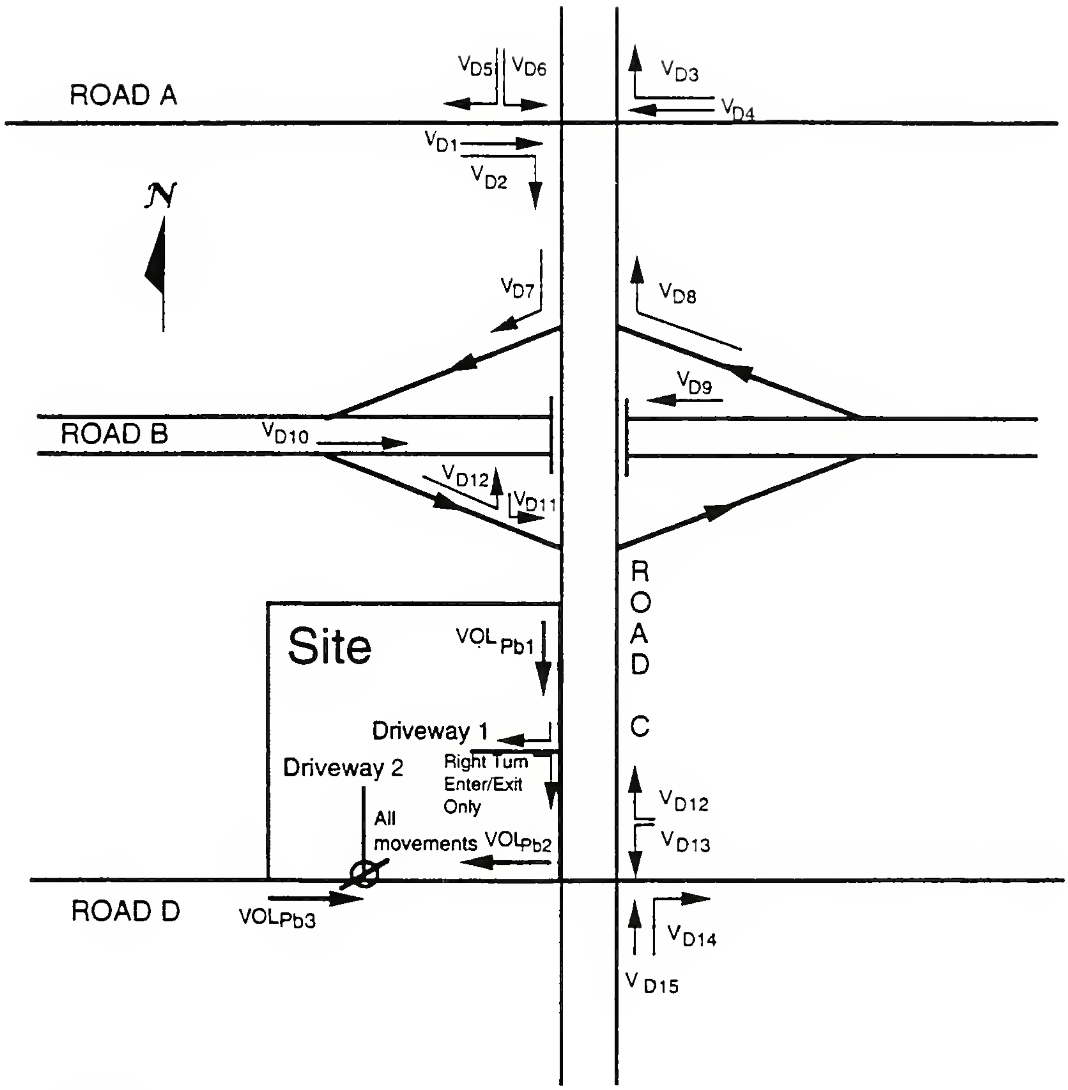
where,

p = probability of a driver, already in the traffic stream, stopping at the generator, $0 \leq p \leq 1$
VOL_{pb} = passing traffic stream volume available to produce pass-by trips
VOL_d = traffic volumes on other streets available to produce diverted linked trips
G = gross leasable area of development (in 1000 sq. ft.)
a_0, a_1 = coefficients to be calibrated

This method is also very data intensive. Therefore, the need for a "quick and dirty method" to estimate pass-by trips was felt.

3.2 Study Objective

The objective of the study was to determine whether it is possible to estimate the percentage of pass-by trips using



Legend

$V_{Pb\ TOT} = \sum VOL_{Pb1} + VOL_{Pb2} + VOL_{Pb3}$ (VPH)

$V_{D\ TOT} = \sum VOL_{D1} + VOL_{D2} + VOL_{D.....} + VOL_{D15}$ (VPH)

Figure 3.1 Identification of Pass-by and Diverted Linked Trip Volumes [Source: Reference 5]

license plate survey instead of the traditional interview survey. Two separate data collection efforts were conducted:

- at Eastway Plaza, a shopping center in Lafayette, Indiana, and
- at a Marsh supermarket store in Castlecreek Plaza, Indianapolis, Indiana.

In both cases, the percentage of pass-by trips obtained by license plate survey were compared with the results obtained by a face-to-face interview survey.

3.3 Data Collection

3.3.1 Eastway Plaza

At Eastway Plaza, the data collection was done in two parts:

a) A group of 13 interviewers intercepted people entering and exiting the different stores and conducted a face-to-face interview survey. The three questions asked were:

i) Where are you coming from?
ii) Where are you going to?
iii) Would you have been traveling on the adjacent roads anyway even if Eastway Plaza was not there?

For the answers to question (i) and (ii), the customers were requested to locate their origins and destinations on a map or were requested to give the name of an intersection or a known landmark.

b) One person was assigned to each of the following locations (see Figure 3.1):

i) Driveway 1 - Access to US 52

ii) Driveway 2 - Access to Greenbush Street (closest to US 52)

iii) Driveway 3 - Secondary access to Greenbush Street

At each of these locations, the last three digits of the license plate of vehicles entering and exiting the shopping center were recorded, along with the time of observation and the movement of the vehicles after exiting/before entering the shopping center parking lot.

Data were collected for one hour during the adjacent evening street peak period on a weekday.

3.3.2 Marsh Supermarket, Castlecreek Plaza

An Indianapolis transportation engineering firm had conducted an interview survey of the customers leaving the Marsh supermarket store at this location. Therefore, at Castlecreek Plaza, only a license plate survey was conducted of the vehicles entering and exiting the plaza by the two driveways, and of customers leaving the Marsh store. Three people recorded the final four license plate characters of the cars entering and exiting the driveways. Two students collected the license plate numbers of customers leaving the Marsh store.

Data was collected on a Friday for one and half hours between 5:00 P.M. to 6:30 P.M.

3.4 Data Analysis

In both cases, the results of the interview survey were analyzed and the data from the license plate survey were stored in an input file according to the following format:

3/4 digits of l/p¦time¦site¦direction of travel

A portion of the input file for Eastway Plaza is shown in Appendix B.

3.4.1 Eastway Plaza

The summary of interview survey results at Eastway Plaza is shown in Table 3.1. The vehicle movements at Eastway Plaza were defined as shown in Figure 3.2.

A matching of the license plate observations was done using a standard computer program. From the results (shown in Appendix B) of the matching and the researchers' ideas about the local travel patterns and adjacent land uses, the trips were classified as primary, diverted, or pass-by. In most of the cases, however, no unanimous decision could be taken regarding the trip type. The results of the matches and the three predicted trip types are shown in Table 3.2.

The total number of matches obtained was 135. From the results of the matches, the following sets of equations were generated:

$T_{PR} + T_{PB} + T_{DI} = 135$ .... (1)

$T_{PB1} = 19$ .... (2)

$T_{DI1} = 25$ .... (3)

$T_{PB2} + T_{DI2} = 41$ .... (4)

Table 3.1. Summary of Interview Survey, Eastway Plaza

STORE NAME	TOTAL # OF TRIPS	PASS-BY TRIPS	NON-PASS-BY TRIPS	NOT KNOWN
B.J.'s	5	0	5	0
Carruso's	15	2	13	0
MVP Sports	6	2	4	0
Aunt Orva's	4	1	1	2
Frame Shoppe	1	0	1	0
Queen City	5	0	3	2
Videoland	59	11	42	6
Fast Food	13	6	7	0
Radio Shack	13	5	5	3
Nutri System	10	1	5	4
Bar Barry	36	13	17	6
Progolf	4	2	2	0
Tropicana	2	0	2	0
Homework	4	0	1	3
TOTAL (PERCENTAGE)	177	43 (28.5%)	108 (71.5%)	26

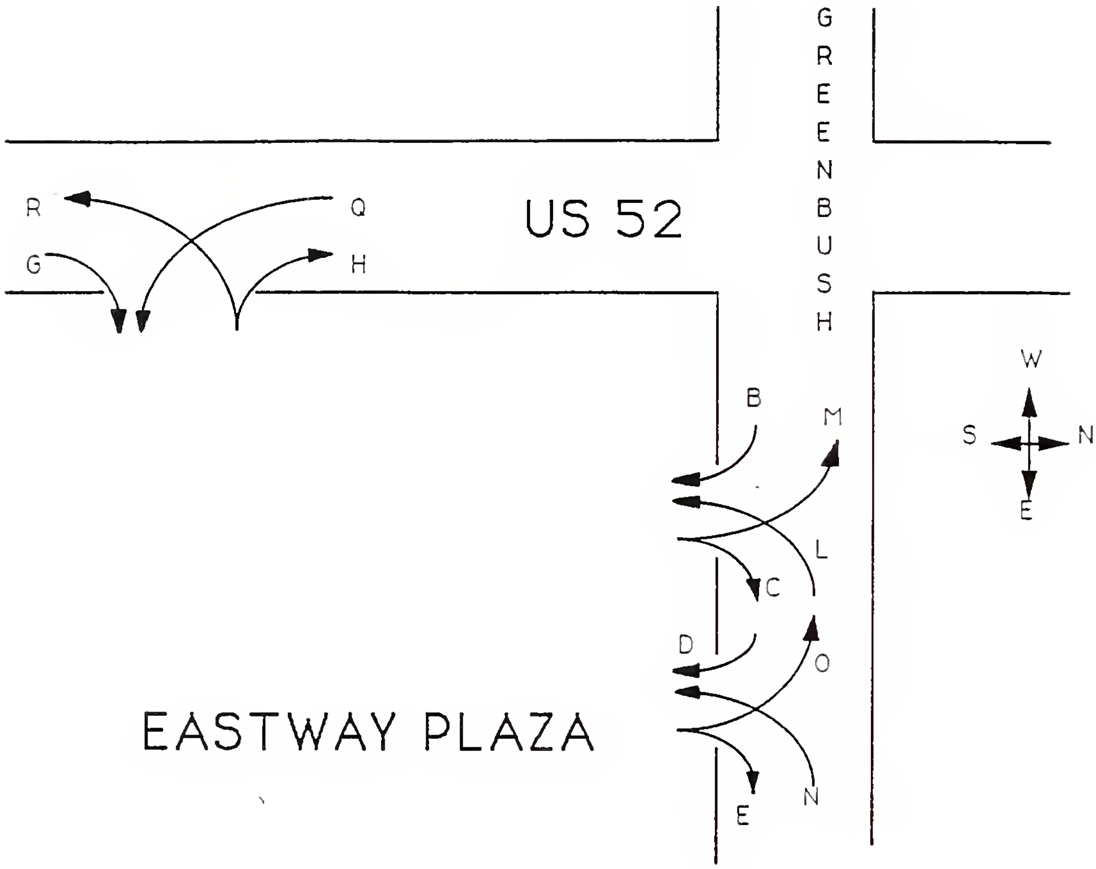


Figure 3.2 Turning Movements at Eastway Plaza

Table 3.2. Results of License Plate Matches at Eastway Plaza

MOVEMENT TYPE	# OF MATCHES	TRIP TYPE	MOVEMENT TYPE	# OF MATCHES	TRIP TYPE
G→H	17	PB/DI	B→C	9	PB/DI
Q→R	3	PB/DI	B→E	10	PB/DI
N→O	0	PB	N→M	1	PB
L→M	1	PB	L→O	1	PB
D→E	1	PB/DI	D→C	0	PB/DI
G→R	17	PR/DI	Q→H	3	PR/DI
B→M	4	PR/DI	B→O	7	PR/DI
L→C	5	PR/DI	L→E	6	PR/DI
D→O	0	PR/DI	D→M	0	PR/DI
N→E	0	PR/DI	N→C	0	PR/DI
G→E	5	PB	G→O	1	DI
G→C	10	PB	G→M	12	DI
Q→E	2	DI	Q→O	0	PR/DI
Q→C	5	DI	Q→M	2	PR/DI
N→R	0	PB	N→H	0	PB/DI
D→R	0	DI	D→H	0	PR/DI
B→R	5	DI	B→H	6	PR/DI
L→R	1	PB	L→H	1	PB/DI

$T_{PR} + T_{DI3} = 50$ .... (5)

where,

$T_{PB} = T_{PB1} + T_{PB2}$ .... (6)

$T_{DI} = T_{DI1} + T_{DI2} + T_{DI3}$ .... (7)

This set of equations reduces to

$T_{PB2} + T_{DI2} = 41$

$T_{PR} + T_{DI3} = 50$

This is a set of 2 equations and 4 unknowns, which has no unique solution.

To circumvent this problem, the trip types were reduced from the three mentioned before (pass-by, diverted and primary) to two -- pass-by and non pass-by. The equations reduced to

$$T_{PB2} + T_{NPB2} = 41$$

This is 1 equation in 2 unknowns, which also has no unique solution.

Two other ways to circumvent the problem faced are:

1) Decide on the trip types based on the turning movements at the adjacent intersections. This could yield an unique solution but in some cases the trip type may still be debatable and subjective. For example in the case of Eastway Plaza, if a license plate survey was conducted at the intersections of US 52/Greenbush and the next intersection towards the south, simultaneous with the surveys at the driveways, it would probably have been possible to decide on the trips types in most of the cases. Due to time constraints this method was not pursued any further.

2) Split up the 2 trip types -- pass-by and non-pass-by and conduct an "extreme analysis". This would provide a range of the percentage of pass-by trips for the proposed development. From the range, a plausible percentage of pass-by trips may be estimated. The analysis was based on this approach.

The results of the matches (based on two trip types -- pass-by and non-pass-by) at Eastway Plaza are shown in Table 3.3.

Table 3.3 Results of License Plate Matches at Eastway Plaza Based on Two Trip Types

MOVEMENT TYPE	# OF MATCHES	TRIP TYPE	MOVEMENT TYPE	# OF MATCHES	TRIP TYPE
G→H	17	PB/NPB	B→C	9	PB/NPB
Q→R	3	PB/NPB	B→E	10	PB/NPB
N→O	0	PB	N→M	1	PB
L→M	1	PB	L→O	1	PB
D→E	1	PB/NPB	D→C	0	PB/NPB
G→R	17	NPB	Q→H	3	NPB
B→M	4	NPB	B→O	7	NPB
L→C	5	NPB	L→E	6	NPB
D→O	0	NPB	D→M	0	NPB
N→E	0	NPB	N→C	0	NPB
G→E	5	PB	G→O	1	NPB
G→C	10	PB	G→M	12	NPB
Q→E	2	NPB	Q→O	0	NPB
Q→C	5	NPB	Q→M	2	NPB
N→R	0	PB	N→H	0	NPB
D→R	0	NPB	D→H	0	NPB
B→R	5	NPB	B→H	6	NPB
L→R	1	PB	L→H	1	PB/NPB

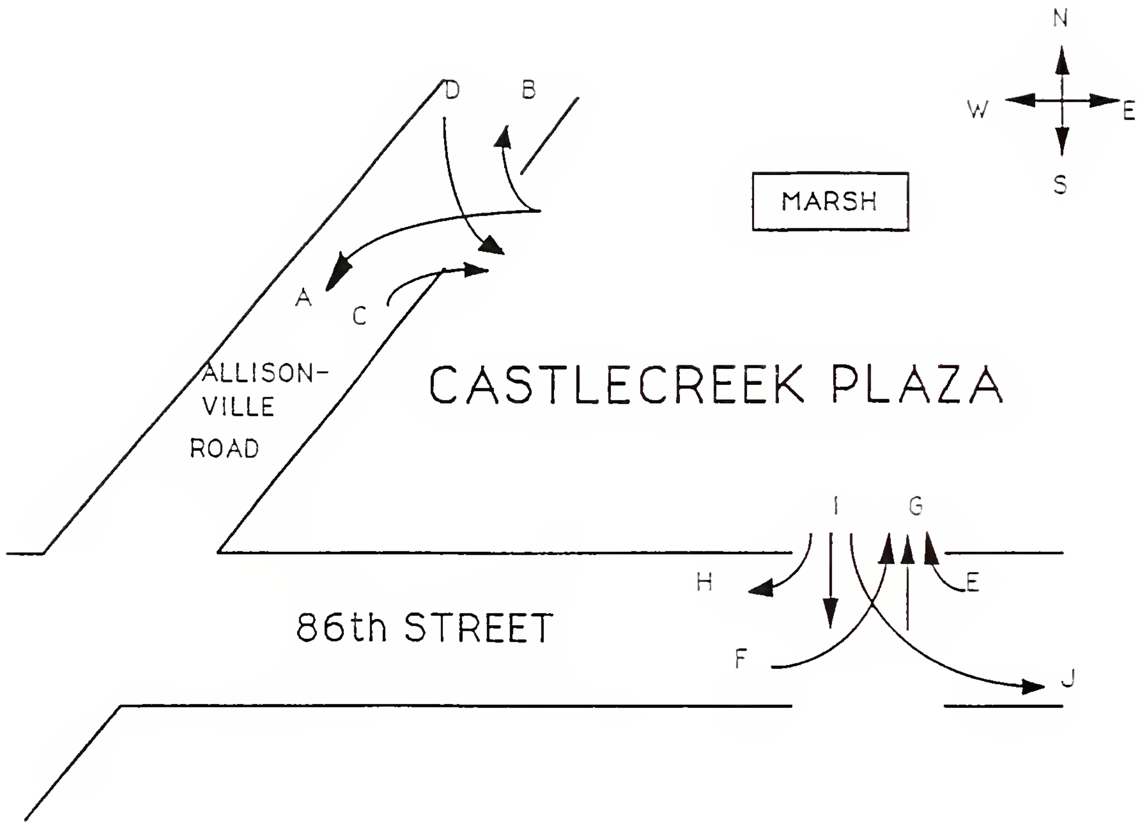


Figure 3.3 Turning Movements at Castlecreek Plaza

Table 3.4 Results of Interview Survey at Marsh Supermarket (Conducted by A&F Engineering, Inc)

TIME	PASS-BY TRIPS	NON-PASS-BY TRIPS
5:00-5:15	4	2
5:15-5:30	5	5
5:30-5:45	6	9
5:45-6:00	6	4
6:00-6:15	5	7
6:15-6:30	6	9
TOTAL (PERCENTAGE)	32 (47%)	36 (53%)

Table 3.5 Results of License Plate Survey at Marsh Supermarket, Castlecreek Plaza

MOVEMENT TYPE	# OF MATCHES	TRIP TYPE	MOVEMENT TYPE	# OF MATCHES	TRIP TYPE
C→A	0	NPB	E→I	6	PB/NPB
C→B	29	PB/NPB	E→J	0	NPB
C→H	2	NPB	F→A	0	NPB
C→I	1	NPB	F→B	6	PB
C→J	2	PB	F→H	3	NPB
D→A	3	PB	F→I	4	PB/NPB
D→B	22	NPB	F→J	3	PB
D→H	3	PB/NPB	G→A	0	PB/NPB
D→I	5	PB/NPB	G→B	11	PB/NPB
D→J	4	PB	G→H	7	PB/NPB
E→A	0	PB/NPB	G→I	1	PB/NPB
E→B	15	PB/NPB	G→J	1	PB/NPB
E→H	6	PB			

3.4.2 Castlecreek Plaza

The results of the interview survey conducted by the consultants is shown in Table 3.4.

The turning movements at Castlecreek Plaza were designated as shown in Figure 3.3.

The results of the license plate matches at Castlecreek Plaza are shown in Table 3.5.

3.5 Results

The total number of matches, number of pass-by trips (PB), number of non pass-by trips (NPB) and number of PB/NPB trips for the two study sites are shown in Table 3.6. PB/NPB trips denote the trips for which no decision could be taken (based on their turning movements) as to whether they were pass-by or non pass-by.

Table 3.6 Summary of Results

	Total Matches	PB	NPB	PB/NPB	PB_{max}	PB_{min}	PB_{avg}	Interview
Eastway Plaza	135	19 (14%)	75 (56%)	41 (30%)	60 (44%)	19 (14%)	39.5 (29%)	28.5%
Marsh	134	24 (18%)	28 (21%)	82 (61%)	106 (79%)	24 (18%)	65 (49%)	47%

PB_{max} and PB_{min} were calculated under the assumption that all the PB/NPB trips were pass-by and non-pass-by, respectively. PB_{avg} was calculated as $(PB_{max} + PB_{min})/2$. Therefore, PB_{avg}

is the number of pass-by trips when there is an equal likelihood of the PB/NPB trips to be pass-by and/or non-pass-by. The percentage of PB_{avg} trips was found to be very close to the percentage of pass-by trips obtained from the interview survey. The results can also be probably explained using order statistics. For a set of observations (x_i), $(x_{max} + x_{min})/2$ is an estimator of the mean of the sample [67].

3.6 Conclusions

The percentage of pass-by trips obtained by a license plate survey in both the cases was found to be very close to the results obtained by an interview survey. However, further studies have to be conducted before the methodology can be accepted as a standard procedure for estimating pass-by trips. At a minimum, the procedure can place upper and lower bounds on the percentage of pass-by trips for a particular existing development. The range will be small if the analyst has a thorough knowledge about the travel patterns in the area and/or if most of the driveway turning movements are unambiguous. The range will also be small if license plate survey includes the adjacent intersections in addition to the driveways.

This method will be especially helpful (in terms of time and manpower) in determining the percentage of pass-by trips for large developments, where a face-to-face interview would be an extensive effort.

CHAPTER 4

BAYESIAN UPDATING OF TRIP GENERATION DATA: COMBINING NATIONAL RATES WITH LOCAL DATA

4.1 Introduction

With traffic impact analysis and impact fee assessment becoming more popular, the need for accurately estimating the trip generation rate of a proposed development is becoming very important. An overwhelming percentage of state transportation agencies depend either partly or entirely on the ITE Trip Generation report to predict the traffic that will be attracted to and/or produced from a proposed development. Analysis of the responses to the survey questionnaire (Chapter 2) revealed that 58 percent of the states depend entirely on the Trip Generation report to estimate the trip generation rate of the proposed development. About 40 percent of the states try to use local data. In the absence of local data, they use the ITE rates. This, however, leads to a problem. The trip generation rates in the ITE report represents a national average, which does not take into account any local characteristics that the site under consideration might have. The Trip Generation report draws the users' attention to this fact and suggests modification of the trip rates to reflect local travel patterns. Many local transportation agencies have local trip generation data, but local officials are usually circumspect about using them because of the small size of the data base. Hence they often go ahead and use the more conventional Trip Generation rates.

This chapter will establish a methodology for obtaining more reliable trip generation rates using Bayesian statistics. The method will show how to use both the ITE *Trip Generation* rates and the available local data base. The procedure discussed in this chapter is an extension of the work done by Mahmassani and Sinha [60], who applied Bayesian updating techniques to cross-classified trip generation rates.

4.2 What is Bayesian Statistics?

In the Bayesian approach to statistics (as opposed to classical statistics), an attempt is made to use all available information so as to reduce the uncertainty present in an inferential or decision-making process. As information is obtained, it is combined with any previous information to form the basis for statistical decisions. The formal mechanism used to combine the new information with the available information is called Bayes' Theorem. The term Bayesian is often used to describe this approach to statistics [56].

In Bayesian statistics, prior information about the possible values of the population mean, as expressed in terms of a prior distribution, is combined with a direct sample evidence to arrive at a posterior distribution [58]. This methodology is more popularly known as Bayesian updating.

4.3 Bayes' Theorem

Suppose we are interested in the values of k unknown quantities

$$\theta = (\theta_1, \theta_2, \ldots., \theta_k)$$

whose values can be expressed in terms of the probability distribution function (p.d.f.), $p(\theta)$. Suppose we then obtain data relevant to their values. More precisely, suppose we have n observations

$$X = (X_1, X_2, \ldots., X_n)$$

which have a p.d.f.

$$p(X|\theta)$$

that depends on θ.

We then want to find a way of expressing our "beliefs" about θ, taking into account both the prior belief and the data. This is done by Bayes' Theorem, which states [66]

$$p(\theta|X) = p(\theta)p(X|\theta) / \Sigma p(\theta)p(X|\theta)$$

Since the denominator depends on X, and not on θ, an alternative form of Bayes' Theorem can be given as

$$p(\theta|X) \propto p(\theta)p(X|\theta)$$

In terms of probability this can be expressed as [59]

$$\left\{\begin{array}{l}\text{posterior}\\ \text{probability of } \theta\\ \text{given the sample}\end{array}\right\} \propto \left\{\begin{array}{l}\text{prior}\\ \text{probability}\\ \text{of } \theta\end{array}\right\} \times \left\{\begin{array}{l}\text{sample}\\ \text{likelihood}\\ \text{of } \theta\end{array}\right\}$$

The terms "prior" and "posterior" in this context are relative ones [58]. For example, prior probabilities may be revised to incorporate the additional evidence of a particular sample. The revised probability then constitutes the posterior. If these probabilities are in turn revised on the basis of another sample, they represent prior probabilities relative to

the new sample information and the revised probability becomes the posterior.

4.4 Use of Bayesian Statistics in Transportation Planning

Formulas and expressions for posterior information parameters have been derived from the basic theorem for application to various general situations. There are several examples of application of Bayesian methodology in transportation planning [63].

Isibor [61] suggested the Bayesian updating technique in the context of modeling the impact of highway improvements on the value of adjacent parcels. Sinha [64] showed how Bayesian statistics could be used by planners in making improved decisions regarding population forecasts. Bayesian updating was also suggested for updating parameters of discrete mode choice models of travel behavior [62] as well as mode choice information in small suburban areas [64]. Chan et al. [65] applied Bayesian methodology to update travel demand elasticities. Bayesian updating has been used to update cross-classified trip generation rates [60].

4.5 Bayesian Updating of Trip Generation Data

In this section we discuss the methodology of applying Bayesian statistics to obtain more reliable local trip generation rates. In this approach the ITE Trip Generation data will be initially assumed to be the prior information. This information will be updated using local trip generation data.

The prior distribution (the distribution of the weighted trip generation rates, i.e., the trip generation per unit of development for a particular land use) is assumed to be normal with mean θ_0 and variance σ_0^2, $N(\theta_0,\sigma_0^2)$. The sampling distribution (local trip generation rates) is also assumed to be normal with mean θ_s and standard deviation σ_s^2, $N(\theta_s,\sigma_s^2)$. However, for the normality assumption to be reasonably valid, the number of data points in both the prior and sampling distributions should be large (preferably 20). For smaller samples, the same model will be valid, but the results might not be reliable because the mean and the standard deviation which enter into the formula, might be affected by unusual generators (outliers). The variance of the two distributions is assumed to be known.

For the situation where both the prior and the sample distributions are normal and the variances are known, the mean and variance of the posterior distribution will be as follows:

$$\theta_p = [\theta_0/\sigma_0^2+\theta_s/\sigma_s^2]/[1/\sigma_0^2+1/\sigma_s^2] \quad \ldots\ldots\ldots(1)$$
$$\sigma_p = [1/\sigma_0^2+1/\sigma_s^2]^{-1/2} \quad \ldots\ldots\ldots(2)$$

The proof of the above is given elsewhere [67]. It also follows that the posterior distribution will be normal $N(\theta_p, \sigma_p^2)$, with mean θ_p and variance σ_p^2. Thus, θ_p, the updated trip generation rate is a weighted average of the original trip generation rate θ_0 and the estimated trip generation rate from the sample, θ_s, the weights being the inverse of their respective variances.

The procedure will be best understood by working through a step-by-step sample calculation. For the purpose of calculation, we will use data from the ITE Trip Generation Report [77; p. 284] for Single Family Dwelling Unit (ITE Code 210), for a typical weekday for our prior information. Therefore, we

have θ_0=26.451, n_0=120, and standard deviation S_0=22.85, where θ_0 is the weighted mean of the number of vehicle trip ends per acre, and n_0 is the number of observations. Let us assume local data with θ_s=20.25, n_s=30, and standard deviation S_s=15.5.

The unbiased estimator of the prior and sample variance will be given by:

$$\sigma_0^2 = S_0^2/n_0 = 22.85^2/120 = 4.35$$
$$\sigma_s^2 = S_s^2/n_s = 15.5^2/30 = 8.00$$

Substituting these values of θ_0, θ_s, σ_0 and σ_s in equations {1} and {2}, we have the new mean updated trip generation rate

$$\theta_p = \{26.451/4.35 + 20.25/8\}/\{1/4.35 + 1/8\} = 24.26$$

and the standard deviation

$$\sigma_p = \{1/4.35 + 1/8\}^{-1/2} = 1.69$$

The resultant posterior distribution will be normal, with mean 24.6 and standard deviation 1.69, $N(24.6, 1.69^2)$.

An important point is that, for the case in which the prior information is reliable and a relatively small sample is used, the posterior distribution of θ will be based primarily on the prior information, as shown in Figure 4.1. For the case shown in Figure 4.2, where the prior information is not very reliable, and a relatively large sample is used, the posterior distribution of θ will be based primarily on the sample information. In both cases, however, the variance of the posterior distribution will always be less than that of both

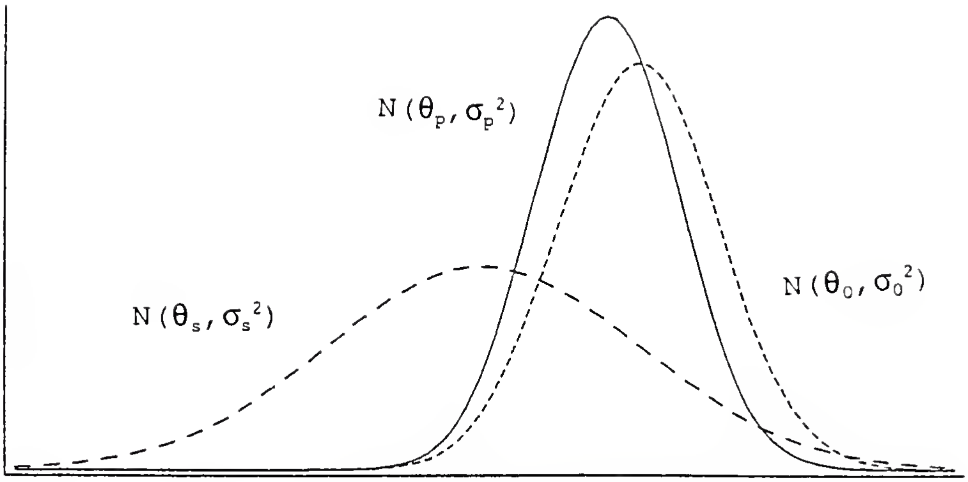


Figure 4.1 Posterior Distribution for Sharp Prior and Flat Sample

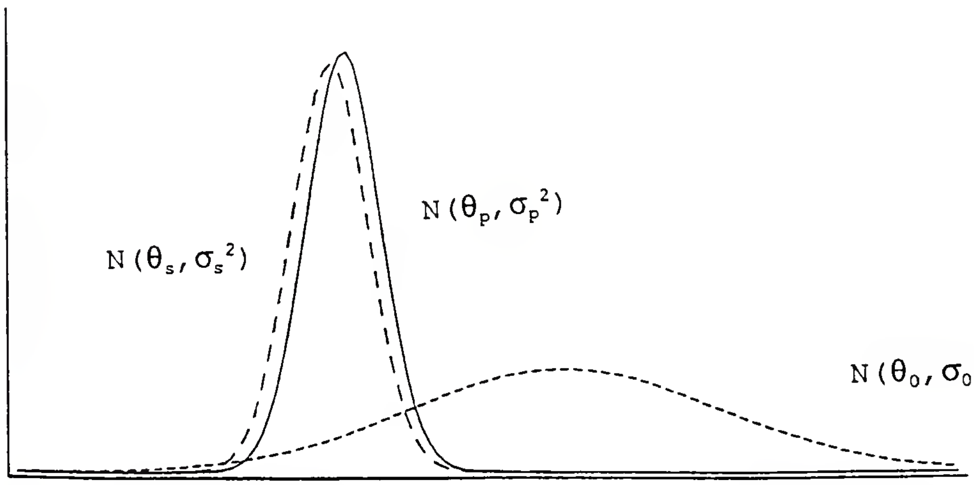


Figure 4.2 Posterior Distribution for Flat Prior and Sharp Sample

the prior distribution and the sample likelihood distribution.

For the sample problem shown above, let us say the local agency conducts another data collection effort after the initial updating has been done. This new information may be used to further update the trip generation rates. In such a case the posterior from the previous study θ_p will simply become the prior of the present study. It has to be combined with the new sample information θ_s' to determine the new posterior θ_p'. Let us demonstrate the case of successive updating by another sample calculation.

Supposing that the local agency conducts another data collection effort and that the new data consist of 20 data points, the average trip generation rate is found to be 19.5 trip ends per acre and the standard deviation is calculated as 13.5. Therefore, for the new sample, we have $\theta_s'=19.5$, $n_s'=20$ and $S_s'=13.5$. The new sample variance will be

$$\sigma_s^{2\prime} = S_s^{2\prime}/n_s' = 13.5^2/20 = 9.11$$

The posterior distribution from the previous updating will simply become the prior of this updating. Therefore, the mean (θ_p') and variance (σ_p') of the new posterior can be calculated as follows:

$$\theta p' = \{24.26/1.69^2 + 19.5/9.11\}/\{1/1.69^2 + 1/9.11\} = 23.12$$
$$\sigma p' = \{1/1.69^2 + 1/9.11\}^{-1/2} = 1.47$$

The new posterior distribution therefore is $N(23.12, 1.47^2)$.

4.6 Use of Subjective Judgment in Bayesian Updating

One of the advantages of the Bayesian updating technique is that the procedure also offers an opportunity to introduce subjective judgments into the model estimation process. If, for example, the data from which the original model has been derived is thought to be unreliable, the variance of the original coefficients can be increased to reduce the weights of these estimates in the updating process. Similarly, if the original estimation has been done a long time ago, the relative weight placed on the prior distribution can be reduced.

Mahmassani and Sinha [60] have proposed a mathematical formulation for incorporating subjective judgment in the updating procedure. The subjective judgment of a group of experienced planners may be used in two ways:

(a) It can provide the prior information in the absence of such information and combined with sample information to derive the posterior.

(b) It can be used as the sample information itself (instead of collecting the information) and combined with an already existing prior distribution.

The formulation is best demonstrated by an example. A group of planners, based on their experience and knowledge of a particular area, decide that the odds that the trip generation rate of a particular land use in the area is between to 20 to 30 trips per hour during the P.M. peak hour of the generator on a weekday, is 9 out of 10. The group also feels that a normal distribution would be appropriate for the parameter. The mean of this distribution will be 25. The variance is calculated by assuming that 90 percent of the area

under the normal curve falls between 20 to 30. Therefore, the remaining 10 percent corresponds to the tail areas and 0.05 corresponds to each tail area. Using a standard normal distribution table, it can be seen that $\alpha = 0.05$ corresponds to Z=1.645. Therefore the standard deviation of the distribution can be calculated using the following formula:

$$(30 - \theta)/\sigma = Z$$

$$\text{or, } \sigma = (30-25)/1.645$$

$$\text{or, } \sigma = 3.03$$

This effectively means that the subjective judgment has been converted to a distribution (prior or sample). Therefore this can be combined with the existing distribution to derive the posterior.

4.7 Conclusion

Bayesian statistics can be very effectively used to update trip generation data. Most of the discussion has concentrated on spatial updating of trip generation rates, which in this case basically involves a global to local transformation of the existing database. This approach can, however, also be used for temporal updating of trip generation rates. Temporal updating is concerned with updating data that have been collected some time ago. Although the national trip generation rates for many land uses tend to be relatively constant over time, the local trip generation rates might change with time due to sudden and drastic changes in the population and economic conditions of the adjacent areas. Bayesian updating can be very effectively applied to such cases. It allows incorporating subjective opinions of experienced planners. The method is economical, since it does not

require extensive data collection efforts for local data to be used in the updating procedure. By combining localized sample data with the already existing information, it gives more reliable local trip generation rates. It permits the use of small survey data, which by themselves would not have been statistically significant. With the traffic impact analysis and impact fees becoming more common, this method can be used to produce reliable data for local application, because an effective analysis depends on the accuracy of the trip generation rates. The use of Bayesian updating can be extended to the case of determining the percentage of pass-by trips for retail developments and the percentage of internal trips in mixed-use developments. The formulas for determining the mean and variance of the posterior distribution will change with the nature of the prior distribution and sample likelihood distribution, but the basic philosophy will remain unchanged.

CHAPTER 5

TRAFFIC IMPACT FEES

5.1 Introduction

In the United States, transportation revenues from traditional sources have been static or declining for a number of reasons [42]. First and foremost, the principal source of revenue in most states is the fuel tax. The increase in gasoline prices, coupled with a more fuel-efficient vehicle fleet that has reduced fuel consumption per vehicle mile of travel, has limited transportation revenues. Second is the fact that the gasoline taxes are typically fixed without adjustment for inflation until extraordinary legislative action is taken. Third, the diversion of highway funds to non-highway purposes have made the situation worse. At the same time, costs of construction, maintenance and labor have been increasing. Major transportation infrastructure like the interstate highway system, much of which was built in the 1960s, is reaching the end of its design life. Coupled with this is the intensification of urban and suburban development. Consequently, public transportation agencies have been sent searching for alternative sources of revenue to maintain an adequate transportation infrastructure.

Most transportation agencies responded to the funding dilemma with increases in fees and taxes from the traditional highway user charges. Since 1975, approximately 90 percent of the states have increased their fuel taxes and most states

have increased their vehicle registration fees [44]. However, local agencies realize that continually raising taxes can not be an ongoing means of meeting budget deficits because of the constant political and public pressure to limit or reduce taxes.

Hence, in many parts of the country, the role of the government in maintaining adequacy began to be redefined. The role of the government may be described by one of the following five scenarios [27]:

1) The government is responsible for providing adequate infrastructure, and the government's inability to do so expeditiously because of limited resources has no bearing whatsoever on whether a land owner shall be allowed to develop his land.

2) The government is responsible for providing adequate infrastructure, and the government's inability to do so expeditiously because of limited resources may require that a land owner's right to develop his land be deferred until those improvements are made.

3) The government is responsible for providing adequate infrastructure, and it should defer development until it can do so. It is a land owner's right, however, if he so desires, to provide adequate infrastructure at his own cost so that development can proceed sooner.

4) The government and major developers share the responsibility of sharing adequate infrastructure, and they must contribute jointly to ascertain that developments and necessary improvements occur simultaneously.

5) The government is responsible for maintaining and administering the existing infrastructure. Anyone further burdening the infrastructure must ensure that the infrastructure remains at an adequate level.

These 5 scenarios indicate a step-by-step evolution away from the government obligation to provide adequate infrastructure. For most of the century, localities operated under scenarios 1 and 2. But with the funding crisis, many jurisdictions have shifted to scenario 3. During the 1980s, some jurisdictions' policies evolved into those of scenarios 4 and 5.

5.2 Methods of Cost Sharing

To supplement the more traditional sources of funding, many agencies, state and local, have tried to involve private interests. The participation takes one of the three forms: voluntary, incentive and mandatory [30]. Under a voluntary arrangement, private sector groups may agree to participate in the transportation projects, but without any legally enforceable commitment to perform. Voluntary arrangements allow transportation projects or programs to be tailored to specific needs and opportunities, and can be easily adjusted to new situations. Since the private involvement is voluntary, local agencies are hesitant to use this approach to alleviate transportation problems. The second method involves providing some form of incentive to the developer, for example, reduction in parking space requirements, in exchange for participation in the funding process. The problem in this method, however, is the identification of a real incentive. Mandatory participation, as the name implies, obligates the developer to take part in financing part or entire highway improvements. It is the mandatory program that has become most popular, because

the incentive and voluntary programs were deemed too risky and awkward.

Local governments have experimented with a variety of methods of private financing of highway projects that are capable of attaining political support and withstanding legal challenge. Private funding of highways has evolved from on-site and minor off-site improvements to the increasing common use of private funds to help finance major highway improvements serving new developments. The major types of private funding that have recently evolved include development agreements, tax increment financing, special assessment districts, impact fees, joint ventures and toll financing [52].

Special assessment districts assess property within a specific area on an annual basis to pay for highway improvements that benefit those properties. Development agreements usually involve the negotiated dedication of land for right of way and the construction or funding of specific highway improvements. Tax increment financing uses a portion of tax revenues from new growth to finance the highway infrastructure needed to serve the new development. Joint ventures include various types of funding involving both public and private funds, usually under a contract among two or more private parties and a public agency. Toll financing is the purest form of user funding and is used in many public agencies to recover the cost of constructing a facility.

5.3 Impact Fees

Transportation impact fees are one-time charges paid by developers who are developing projects that will create new impacts on the transportation system. The fee is assessed

specifically to allow the local government to provide build the transportation capacity necessitated by new developments. New developments may be either "brand new" or renovation, as long as the project creates new impacts. The fees cannot be assessed to perform operational or maintenance activities.

5.4 Impact Fee Structure

Impact fees are usually calculated based on the three basic approaches discussed below.

5.4.1 Last Developer In

Many jurisdictions do not charge impact fees as long as adequacy is not threatened. Thus the initial few developers that come in after some government-funded roadway improvements have been made do not pay any impact fees, although their impacts may be substantial. Ultimately the time comes when the next developer causes conditions of inadequacy. This developer has to pay for roadway improvements, although his individual impact may be relatively small. The developers coming in after him may be able to take advantage of the roadway improvements provided for by him until adequacy is again threatened [27].

This method of charging impact fee is the crudest and perhaps the oldest. But it is intrinsically unfair and is no longer very popular, because it can easily be challenged in a court of law.

5.4.1 Facility-Based Fees

Facility-based fees are calculated by estimating the transportation facilities that will be required in the horizon year to maintain adequate operational conditions on the roadway infrastructure. The cost of construction of new facilities are divided by the estimated trips generated by new/proposed developments to obtain the unit cost or cost per trip. The impact fee is calculated by multiplying the unit cost by the estimated trip ends for the development.

$$C_u = C/\Sigma T_i$$

where,

C_u - unit cost per trip
T_i - # of trip ends for development i
C - construction cost of the facility

$$C_i = C_u \times T_i$$

where,

C_i - impact fee to be paid by development i

Facility-based fees have been challenged because they are not sensitive to the difference in total demand for transportation services (expressed in lane-miles of highway used up by site-generated traffic) associated with each of the different land uses. They are also not sensitive to the revenues for road construction that were projected to be generated by new developments [25].

5.4.2 Consumption-Based Fees

The consumption-based fees take into account trip characteristics information and recognize as credits the revenues generated for roadway improvements by travel asso-

ciated with new developments. The fee formula for consumption-based fees is as follows [26]:

Impact Fee = Demand X Cost - Credits

Demand X Cost = (Total new trips X trip length X Unit Cost)/(2 X capacity/lane)

Unit Cost = Cost to construct 1 lane-mile of roadway

The impact fee formula assumes a 50 percent directional split.

Credit = Gas tax credits + other infrastructure tax credits

Gas Tax Credits = (trip rate X trip length X capture rate X equivalent days/year X cents/gallon X PWF)/MPG

capture rate - percentage of "new trips" attracted by the development
equivalent days/year - for work trips this will be equal to the number of actual working days in a year
PWF - present worth factor
MPG - miles per gallon

"Other infrastructure tax credits" may include, among other things, future capital revenue that would be collected because of the new growth.

The theory behind the consumption-based fee is that the new development is charged based on the value of the system that it will consume and does not include a share of the system that needs to be constructed for other reasons.

To properly apply this method, data have to be available for trip rate, trip length, and capture rate, along with future capital costs and revenues.

5.5 Case Studies

This section will deal with the impact fee structure in some local agencies in America.

5.5.1 Montgomery County, Maryland

The impact fee is determined using the following steps [49]:

1) First the cost between the public and private sector is apportioned using the following formula:

$$\text{Private sector share} = (RD/TD) \times 100$$

where,

RD - Remaining development that can be permitted under the master plan
TD - Total development at build-out.

If the percentage obtained is greater than 50 percent, then the private sector share is 50 percent. If the percentage is less than 50, then the private sector share will be equal to the percentage calculated.

2) The travel impact index (TII) for each land use category is derived according to the following formula:

$$(TII)_i = PHTG \times (100\text{-}PB\%) \times \text{trip length}$$

PHTG - Peak hour trip generation
PB - Pass-by trips

3) Trip impact value (TIV) for each land-use category is calculated according to the formula:

$$(TIV)_i = (TII)_i \times RD$$

4) The transportation impact fee (TIF) is calculated as follows:

TIF = Roadway improvement cost X private sector share

5) The impact fee per unit of land use i calculated according to the following formula:

$$(TIF)_i = [(TIV)_i/\Sigma(TIV)_i] \text{ X TIF X } 1/\# \text{ of units}$$

One result of this method is that the per unit fee for a particular land use varies from one area to another, since 3 of the 4 factors (private sector share, road program cost and remaining development by land use) differ.

5.5.2 TRIPS Model, Broward County, Florida

TRIPS is a computer model used to determine the impact fee in Broward County, Florida [41]. The model estimates the number of trips entering and exiting the development, simulates where they will go in the county and which roads they will use. For a development to be subject to a transportation impact fee, the following two conditions must be satisfied [48]:

i) Segments in the roadway system affected by the development must currently be over capacity.

ii) An improvement to the roadway capacity must be included in the Broward County long-range transportation plan.

If these criteria are met, a fee is calculated based on the development's share of the additional traffic that the planned improvement will accommodate and on the estimated cost of the improvement. The fees for the individual roadway seg-

ments added together produce total road impact fee for the development. An example follows.

Suppose we have a development i producing T_i trip ends. Let T_{ij} denote the number of trips produced by the development i that use link j. If link j satisfies conditions (i) and (ii) stated above, then the impact fee C_{ij} for T_{ij} will be given by,

$$C_{ij} = C_j \times T_{ij}/(C_{horizon} - C_{base})$$

where, $C_{horizon}$ and C_{base} denote the capacity of link j under improved and present conditions, respectively, and C_j is the cost of improving roadway j. The total impact fee for the development will be given by:

$$\text{Impact Fee} = \Sigma\, C_{ij}$$

with C_{ij} summed over the road segments j that meet criteria (i) and (ii).

5.5.3 Palm Beach County, Florida

In Palm Beach County, Florida, land uses are primarily categorized into 2 categories: residential and non-residential. The basic formula takes into account the trip generation rate of the development and the cost of construction of additional highway lanes and lane capacities.

The basic fee structure is as follows [45]:

Residential Fees = (1/2 external trips/1 lane capacity) X
(cost to construct of 1 lane for 3 miles)

Non-residential Fees = (1/2 external trips/1 lane capacity)X
(cost to construct 1 lane for 1 mile)

The underlying assumption is that non-residential trips are often captured from traffic already in the traffic stream and have a shorter trip length. An external trip is one that has a trip end at the development under consideration. Only half of the trips are taken into account, assuming a 50 percent directional split.

5.5.4 Hillsborough County, Florida

The impact fee is calculated using the formula [69]:

Fee = (# X TGR X TL)/ CLM/2 X CC X (1-ILR) X PC

where,

\# - the land use intensity (dwelling units for residential and 1000's of square feet for non-residential)
TGR - ITE trip generation rate for the land use
TL - average trip length
CLM - capacity per lane mile at LOS D
CC - cost to construct one lane mile
ILR - interstate and local roads adjustment
PC - percentage charge to impact fee

The ILR factor reduces the estimated traffic by a certain factor because of interstate through traffic and local roads exclusion. A percentage charge is determined to be the minimum fee used in conjunction with existing gasoline tax revenues that would provide a LOS D.

5.5.5 Reserve Capacity Approach, Hudson, New Hampshire

The impact fee structure in New Hampshire is based on the concept of available reserve capacity (ARC) and involves the following steps [31]:

1) Establish base traffic volumes in the horizon year
2) Calculate capacity of improved roadway segments
3) Determine the available reserve capacity for segment i, $(ARC)_i$

$$(ARC)_i = C_{improved} - C_{base}$$

$C_{improved}$ - capacity of improved roadways
C_{base} - capacity of improved roadway used up by base traffic.

4) Identify roadway improvement costs to be allocated to future developments that are responsible for using up the reserve capacity. The cost to be allocated for a given highway segment is given by:

$$(ARC_i/C_{improved}) \text{ X cost to improve segment}$$

5) The impact fee for a development is given by;

$$(\text{Segment ARC used by development/Total segment ARC}) \times \text{Allocable segment cost}$$

5.6 Legal Aspects of Impact Fees

Laws regarding impact fees have changed significantly over the past two decades. Previously, the courts either tended to look on such fees with suspicion -- as invalid taxation against new developments -- or to uphold them under the loose "hands-off" approach, considering them as necessary corollaries to local land use regulations. Today, however the courts increasingly apply a stricter cost accounting approach to development impact fees, as well as other types of development exactions. They try to determine the fees' validity by

closely examining the means by which the fees accomplish their purposes [38,39].

The courts increasingly base the validity of impact fees on the rational nexus test [38]. Consequently, many planners, attorneys and developers now view rational nexus as the mainstream approach to setting impact fees.

The rational nexus test chiefly involves two principles. First, there must be a reasonable connection between community growth that the new development generates and the need for facilities to serve that growth. Second, there must be a connection between the expenditure of the fees collected from a contributing development and the benefits that the development will enjoy. The rational nexus test requires the local governments to show that growth will result in a need for new facilities that impact fees assessed against new developments will finance and that the funds collected will not only provide the needed facility but will also benefit the contributing development.

Therefore, communities must demonstrate that needs for additional facilities result from new developments, not from existing deficiencies. To make that decision, communities need to determine appropriate facility standards in the general planning process, then formulate a capital improvement program plan under which they will schedule improvements to correct existing deficiencies, upgrade level of service to the predetermined acceptable value, and anticipate further improvements that new developments will make necessary. They can then apportion facility costs between current and new developments.

The rational nexus test does not require that contributing developers exclusively benefit from facilities financed

by impact fees. The relevant issue is whether they substantially benefit. Under the "substantial benefit rule", the relevant criterion is the location of the improvement. Locating the improvement where one may reasonably expect the occupants of the development would use the improvement meets the substantial benefit rule. No technical standard defines the substantial benefit rule.

5.7 Developers View on Impact Fees

In principle, developers believe that impact fee financing represents a shrinking of public responsibility for financing the infrastructure necessary to support community development. They are, however, willing to put practice before principle to launch a potentially profitable project. In that respect, they view impact fees as the least of the three evils -- the other two being a halt to all development until adequate public funds are accumulated to provide the roadway infrastructure improvements necessitated by the development and the exaction of developer contribution through case-by-case negotiations [43].

The two major concerns of the developers are the equity issue and the benefit issue. The first concern is that impact fees are not intrinsically fair to the new tenants or residents, to whom it is usually passed on. This extra cost added to the already existing taxes and fees tend to overcharge the new residents, who end up paying more than their fair share of the infrastructure cost. On the second issue, developers suspect that the improvements will benefit the entire community and not just them and their tenants/residents. Added to this is the fact that the funds might be used to alleviate existing infrastructure deficiencies and problems.

With the passing of time, however, developers are realizing that impact fees are a reality and a necessity if development is going to proceed in an orderly fashion. They want the fees to be adopted, formulated, and administered fairly and reasonably, so that they understand why a fee is needed, how it will be determined, when and where it is going to be used, and what effects it will have on their projects.

5.6 Recommendations

There seems to be little room for doubt that, with rising construction costs, reduction in federal and state support, increased maintenance costs because of the decaying transportation infrastructure and the local government's inability to raise taxes to meet the budget deficit, impact fees as a form of private/public cost sharing to provide transportation improvements necessitated by new developments have a proper role to pay.

There are still a few unresolved issues and debatable topics in the area of impact fee assessment and their effects on society. The debate is expected to continue. Many agencies have established impact fees to fund a part or all of the highway improvements necessary to accommodate new developments. There exists a growing body of literature available to assess the success or failure of the different impact fee structures used by local agencies.

Recommending a particular impact fee formula or procedure to be used in the state of Indiana is beyond the scope of the project. It would require a more thorough survey of the literature available, the legal issues involved, the data base available, etc. Moreover, the issue of impact fee assessment is usually dealt with at the local level to take into account

local characteristics and public attitudes. Some states have established statewide impact fee guidelines, but this is the exception rather than the rule. Therefore, this section will only comment on the different procedures and recommend the steps to be taken for setting-up an impact fee structure.

The consumption-based approach is intrinsically the most fair, but it would involve data on trip lengths for different land uses. The facility-based system of impact fee assessment is much simpler to calculate. What is acceptable should be based on the type of data and information that are available. However, the fee structure should be defensible in a court of law, and satisfy the rational nexus test described earlier in the chapter. It should also be based on the basic principles of equity and consistency.

Following are some guidelines to be followed when developing an impact fee structure.

1) Avoid Surprises -- Developers are likely to feel threatened if they are surprised by poorly publicized legislation. Communities should develop a fee structure through a public/private discussion process that includes representatives from all the parties involved. Such a process provides an opportunity to educate all the parties about the needs and objectives. This would also allow for reconciliation of differences before discussions enter the public arena about specific cases. Loveland, Colorado followed such a procedure to develop its impact fee structure, which has been very successful so far.

2) A Planning Framework -- Developers will be more willing to contribute to developing the public infrastructure system if they know that the responsible planning agency has a well-defined program for system expansions. They want to see

their money well spent for facilities of proven need that are efficiently planned.

3) Reasonable Formulation -- Governments too often calculate impact fees in a way that relates all future infrastructure costs to the amount of new development expected. Facility impacts should reflect the marginal increases in needs that the new development causes and should exclude existing deficiencies in facilities.

4) Responsible Administration -- The fees paid by the developers should find their way speedily and efficiently into specific capital improvements that directly benefit the payers project. A time limit should be specified within which the funds have to be spent.

CHAPTER 6

FUTURE RESEARCH

6.1 Further Studies

Further studies that could improve the conduct and value of traffic impact studies in Indiana are suggested below.

1) Access Management Regulations -- One of the frequent problems encountered by the Indiana Department of Transportation is maintaining the operational and functional integrity of the state highway system in the absence of a sound and efficient access control policy. Developers often request driveways close to intersections, frequent median cuts/breaks along a divided state highway, etc. These can result in vehicles randomly exiting and entering highways, thereby creating operational and safety problems and also reducing the ability of the facility to carry the intended volumes of traffic. A study could be conducted to develop policies that would enable INDOT to control access in a consistent, objective and reasonable manner. This would improve the traffic flow, increase capacity, and enhance the safety of the state highway system.

2) Traffic Impact Fees -- This study made a brief review of existing traffic impact fee structures and made certain recommendations. It seems, however, that with the present shortage of local funding, traffic impact fees have an important role to play. If local agencies in Indiana wish to implement impact fees, a careful study has to be conducted to

look into the existing ordinances, legal aspects, the advantages and disadvantages of the various approaches to impact fee structuring, the mechanism of collecting and spending impact fees, etc.

3) Application of Bayesian Statistics -- Studies could be conducted to identify and test further applications of the Bayesian updating technique discussed in this thesis. It could be possible to use Bayesian updating techniques to estimate the percentage of pass-by trips for a particular type and intensity of land-use and to find out the percentage of internal trips for mixed-use developments. The basic updating philosophy should remain the same. Only the formulas for the mean and variance of the posterior distribution will have to be derived based on the distribution of the prior and sample likelihood distributions. Another problem of theoretical interest would be to conduct a robustness analysis to determine how much the end results of the updating procedure depend on the normality assumption (of the prior and sample likelihood distribution).

4) Estimation of Pass-by Trips -- Further data collection and analysis have to be conducted to verify or refine the proposed methodology for estimation of pass-by trips. An investigation has to be conducted to determine whether the results can be explained using "order statistics".

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APPENDICES

APPENDIX A

QUESTIONNAIRE

STATUS OF TRAFFIC IMPACT ANALYSIS AND IMPACT FEES IN TRANSPORTATION AGENCIES

1. a) Name of Agency:
   b) Name, telephone number and job position of the person completing the questionnaire:

2. Which statement best characterizes your agency? (Circle one)
   a) We already have a standard methodology for evaluating traffic impacts of new developments.
   b) We are trying to establish a standard methodology for evaluating traffic impacts of new developments.
   c) We do not conduct any traffic impact study for proposed posed developments.

3. Do you have any on-going research in your organization on Traffic Impact Analysis? Yes/No
   If yes, please describe, on a separate sheet, the nature of the research project.

   If you circled 2c and your answer to question 3 was no, please go to 10. Otherwise continue.

4. At what stage of the development process is a traffic impact study considered?

5. Based on what criteria do you decide whether a detailed traffic impact analysis is necessary for a particular development? Please indicate the threshold value in each case.
   a) Predictor variables (development size,# of employees etc.)
   b) Trip generation rates (peak hour trips, daily trips, etc.)
   c) Others (please specify)

6. How do you establish trip generation rates for a proposed development? (Circle one)
   a) Use national standards (please specify)
   b) Use local trip generation rates (please indicate source)
   c) Others (please specify)

7. How do you estimate pass-by trips? (Circle one)
   a) Use percentage in ITE Trip Generation report
   b) Collect data
   c) Others (please specify)

8. How do you estimate trip generation rates for mixed land-use developments? (please use separate sheet)

9. What does your agency assume to be an acceptable level of service (LOS) on the adjacent roadway network and intersections?

10. Do you charge impact fees from the developers? Yes/No

    If your answer is no stop here. Otherwise continue.

11. At what stage of development are impact fees charged? (Circle one)
    a) Building permit
    b) Access driveway permit
    c) Other (please indicate)

12. Do you charge impact fees from the developers if a traffic impact study reveals that :
    a) there is no change in the level-of-service due to the site - generated traffic. Yes/No
    b) the adjacent roadway network's LOS will worsen, but it will still operate at an acceptable LOS, even with the site-generated traffic. Yes/No

13. How do you estimate the impact fees to be paid by the developer? (Please indicate on separate sheet)

14. Please indicate on separate sheet, how you assess the impact fees for piecemeal developments?
    (A series of developments with small individual traffic impacts, but large collective impacts)

15. Is the developer allowed to do the following in lieu of paying cash?
    a) Donate land for right-of-way.
    b) Make off-site roadway improvements.
    c) Others (please specify)

16. Has your agency faced any legal challenge to the concept of impact fees? Yes/No

17. What is the biggest problem, if any, that your agency has faced in the field of traffic impact analysis and/or traffic impact fees? (Please use separate sheet, if required)

APPENDIX B

PORTION OF SAMPLE INPUT DATA FILE FOR EASTWAY PLAZA

563	174300	D	WB
265	174600	D	WB
016	170800	E	EB
376	171000	E	EB
85Z	171000	E	WB
74Z	171130	E	EB
27Z	171145	E	WB
42Y	171300	E	EB
554	171300	E	WB
205	171500	E	WB
431	172000	E	EB
109	172700	E	EB
59B	172800	E	EB
197	173200	E	EB
42A	173300	E	EB
07Y	173300	E	WB
183	173400	E	EB
211	173600	E	EB
07Z	173800	E	EB
625	173800	E	WB
295	174000	E	EB
433	174100	E	EB
737	174200	E	EB
84Z	174200	E	WB
589	174300	E	EB
520	174500	E	EB
271	174600	E	EB
709	174700	E	EB
10Z	174800	E	EB
925	175300	E	WB
386	175600	E	WB
82Y	175900	E	EB
27Y	180300	E	EB
102	180300	E	EB
988	180300	E	WB
264	180400	E	WB
811	170500	F	NB
255	170630	F	WB
374	170800	F	WB
252	171000	F	WB
307	171230	F	WB

818	171500	F	NB
542	171700	F	WB
418	171900	F	NB
340	172000	F	NB
332	172500	F	SB
07Z	173000	F	SB
5MI	173500	F	SB
68Z	173730	F	WB
111	174000	F	SB
239	174230	F	WB
418	174500	F	WB
967	174600	F	WB
960	174700	F	NB
190	174800	F	SB
56T	175000	F	SB
319	175230	F	NB
894	175500	F	WB
707	175600	F	NB
60Z	175700	F	NB
439	175800	F	WB
73M	180000	F	NB
841	180100	F	WB
122	180200	F	NB
27M	180300	F	SB
750	170500	G	NB
92Z	170540	G	NB
915	170605	G	NB
731	170620	G	NB
74Z	170730	G	NB
07Z	170800	G	NB
604	170830	G	NB
66Z	170840	G	NB
918	170900	G	SB
808	170910	G	NB
670	170920	G	NB
198	171000	G	SB
242	171010	G	NB
427	171030	G	NB
418	171045	G	NB
761	171100	G	NB
075	171115	G	NB
731	171150	G	NB
082	171340	G	NB
284	171405	G	NB
340	171420	G	NB
216	171435	G	NB
448	171440	G	NB
183	171447	G	SB
98Z	171455	G	NB
243	171500	G	SB
49Z	171525	G	SB
232	171540	G	NB

PART OF SAMPLE OUTPUT FILE FOR EASTWAY PLAZA

```
"New" trips using major Greenbush and US52 driveways (B->H)

Plate  Travel Time
----------------------------
186      200
295      340
381      2610
433      330
751      3250
820      300
----------------------------
 "New" trips using major Greenbush and US52 driveways (B->H)
 Plates Matched           :      6
 Minimum Practical Distance : 0.21
 Average Speed (MPH)      :   0.65
 Average Time (seconds): 1171.66

----------------------------
"New" trips using major Greenbush and US52 driveways (B->H)
Plates Unmatched        :     87



Diverted trips using major Greenbush and US52 driveways (B->R)

Plate  Travel Time
----------------------------
195      230
294      285
334      835
762      450
884      125
----------------------------
Diverted trips using major Greenbush and US52 driveways?
(B->R)
 Plates Matched           :      5
 Minimum Practical Distance : 0.21
 Average Speed (MPH)      :   1.96
 Average Time (seconds): 385.00

----------------------------


Diverted trips using major Greenbush and US52 driveways (B->R)
 Plates Unmatched         :    108
```

```
"New" trips using minor Greenbush and US52 driveways (D->H)

Plate  Travel Time
----------------------------
----------------------------
 "New" trips using minor Greenbush and US52 driveways (D->H)
 Plates Matched          :      0
 Minimum Practical Distance : 0.23
 Average Speed (MPH)    : 828.00
 Average Time (seconds):  1.00

----------------------------
 "New" trips using minor Greenbush and US52 driveways (D->H)
 Plates Unmatched        :     40



Diverted trips using minor Greenbush and US52 driveways (D->R)

Plate  Travel Time
----------------------------
----------------------------
Diverted trips using minor Greenbush and US52 driveways (D->R)
 Plates Matched          :      0
 Minimum Practical Distance : 0.23
 Average Speed (MPH)    : 828.00
 Average Time (seconds):  1.00

----------------------------
Diverted trips using minor Greenbush and US52 driveways (D->R)
 Plates Unmatched        :     59



Passby trips using US52 and major Greenbush driveways (G->C)

Plate  Travel Time
----------------------------
033      1035
075      405
100      325
242      20
367      1480
368      60
670      3040
760      370
915      115
98Z      125
----------------------------
```

Passby trips using US52 and major Greenbush driveways (G->C)
Plates Matched : 10
Minimum Practical Distance : 0.21
Average Speed (MPH) : 1.08
Average Time (seconds): 697.50

Passby trips using US52 and major Greenbush driveways (G->C)
Plates Unmatched : 121

Passby trips using US52 and minor Greenbush driveways (G->E)

Plate	Travel Time
07Z	1800
42A	387
520	105
71Z	1457
74Z	240

Passby trips using US52 and minor Greenbush driveways (G->E)
Plates Matched : 5
Minimum Practical Distance : 0.23
Average Speed (MPH) : 1.04
Average Time (seconds): 797.80

Passby trips using US52 and minor Greenbush driveways (G->E)
Plates Unmatched : 106

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